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TITLE OF THE INVENTION:

METHOD AND DEVICE FOR DETERMINING WEAR OF COMPOSITE
MATERIAL BRAKE DISKS OF A ROAD VEHICLE

10 The present invention relates to a method and device
for determining wear of composite material brake disks of
a road vehicle.

BACKGROUND OF THE INVENTION

At present, all road racing vehicles (cars and
15 motorcycles) are equipped with metal-disk brakes. On the
basis of experience acquired in racing applications, disk
brakes with disks made of composite material (in
particular, composite ceramic material such as carbon -
so-called "CCM disks") have been proposed, by providing
20 for improved braking performance as compared with metal
disks.

In actual use, however, composite material brake
disks have been found to deteriorate rapidly, with
consequent impairment in mechanical characteristics and
25 fatigue resistance. In particular, over and above a given
wear threshold, composite material brake disks fail to
ensure safe operation, so that, in a road vehicle
equipped with such disks, it is imperative that wear of

the disks be determined accurately to inform the driver promptly of the need to replace the disks.

To determine wear of a metal brake disk, it has been proposed, as described for example in Patent US6345700, to use a sensor fitted to and for measuring the thickness of the disk. This solution, however, cannot be applied to composite material brake disks, on account of the sensors not normally having the necessary wear-detecting precision. Moreover, the sensors are relatively expensive, by being called upon to measure wear of a component - the brake disk - rotating at high speed in a dirty environment (further compounded by the dust produced in use by composite material brake disks).

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method and device for determining wear of composite material brake disks of a road vehicle, which are cheap and easy to implement and, at the same time, provide for eliminating the aforementioned drawbacks.

According to the present invention, there is provided a method of determining wear of composite material brake disks of a road vehicle, as claimed in Claim 1.

According to the present invention, there is provided a device for determining wear of composite material brake disks of a road vehicle, as claimed in Claim 16.

BRIEF DESCRIPTION OF THE DRAWING

A non-limiting embodiment of the present invention will be described by way of example with reference to the accompanying drawing, which shows a schematic view of a vehicle featuring a central control unit operating
5 according to the method of the present invention.

DETAILED DESCRIPTION OF THE INVENTION

Number 1 in the accompanying drawing indicates a vehicle having four wheels 2 (two front wheels and two rear drive wheels), and comprising a front internal
10 combustion engine 3, and a brake system 4 having four brake disks 5, each of which is located inside a respective wheel 2, and is fitted to a corresponding calliper 6 controlled by a brake pedal 7 in the passenger compartment of vehicle 1.

15 Brake disks 5 of vehicle 1 are made of composite material, in particular carbon (composite ceramic material), and brake system 4 comprises a central control unit 8 for determining and storing an estimate of the wear of brake disks 5, so as to generate a driver signal
20 when the wear of brake disks 5 exceeds a given safety threshold.

Central control unit 8 is connected to a speed sensor 9, which is fitted to one of front wheels 2 to real-time detect the value $v(t)$ of the travelling speed
25 of the vehicle, and transmit value $v(t)$ to a speedometer on the instrument panel (not shown in detail) of vehicle 1. Central control unit 8 is also connected to a brake sensor 10, which is fitted to brake pedal 7 to determine

operation of brake pedal 7 to command the stop lights (not shown in detail) of vehicle 1. It is important to note that both speed sensor 9 and brake sensor 10 are normally already provided on vehicle 1. Central control
5 unit 8 is therefore cheap and easy to install, by operating with existing signals on vehicle 1.

Central control unit 8 stores a total wear value U of brake disks 5, which is reset whenever brake disks 5 are changed.

10 In actual use, central control unit 8 constantly monitors the speed $v(t)$ of vehicle 1 with a given control frequency, to determine all the decelerations of vehicle 1, i.e. all the situations in which the speed $v(t)$ of vehicle 1 falls from an initial value V_1 to a final value
15 V_2 . At each deceleration of vehicle 1 brought about by actual operation of brake system 4 (as determined by brake sensor 10), central control unit 8 determines an instantaneous wear contribution u of brake disks 5 during deceleration, and updates the total wear value U of brake
20 disks 5 by adding the instantaneous wear contribution u of brake disks 5 during deceleration to the previous total wear value U . The central control unit therefore ignores any deceleration of vehicle 1 not brought about by actual operation of brake system 4, but by friction on
25 vehicle 1 (mainly engine braking, tyre-road friction, and drag).

The total wear value U of brake disks 5 preferably comprises a total wear value U_a of the front brake disks

5, and a total wear value U_p of the rear brake disks 5; and the instantaneous wear contribution u of brake disks 5 during deceleration is divided between the two total values U_a and U_p as a function of a constant distribution ratio, or a variable distribution ratio (typically calculated at each deceleration as a function of the initial and final speed values V_1 and V_2 of the deceleration).

To determine the actual value of the instantaneous wear contribution u of brake disks 5 during deceleration brought about by actual operation of brake system 4, central control unit 8 calculates the kinetic energy differential DE_k of vehicle 1 induced by deceleration; determines, as a function of the kinetic energy differential DE_k of vehicle 1, an instantaneous value E_d of the energy dissipated by brake disks 5 during deceleration; and determines the value of the instantaneous wear contribution u of brake disks 5 during deceleration on the basis of the value E_d of the energy dissipated by brake disks 5 during deceleration. The kinetic energy differential DE_k of vehicle 1 induced by deceleration is calculated according to the following equation:

$$DE_k = 0.5 * M * (V_1^2 - V_2^2)$$

where V_1 is the initial speed of vehicle 1, V_2 is the final speed of vehicle 1 (lower than speed V_1), and M is the mass of vehicle 1.

The instantaneous value E_d of the energy dissipated

by brake disks 5 during deceleration is typically assumed equal to the kinetic energy differential DE_k of vehicle 1. The instantaneous wear contribution u of brake disks 5 during deceleration is determined by multiplying the value E_d of the energy dissipated by brake disks 5 during deceleration by a multiplication constant K ranging between 0 and 1; and the value of constant K is calculated experimentally by means of road and/or track tests.

10 In an alternative embodiment, at each deceleration, an energy contribution caused by the braking action of friction on vehicle 1 is determined; and the instantaneous value E_d of the energy dissipated by brake disks 5 during deceleration is assumed equal to the difference between kinetic energy differential DE_k and the energy contribution caused by the braking action of friction on vehicle 1. By way of example, the energy contribution caused by the braking action of friction on vehicle 1 may be determined as a function of the speed of vehicle 1, since friction due to drag substantially depends on speed, and as a function of engine speed, since engine braking substantially depends on the speed of the engine.

25 Wear of brake disks 5 has been found to depend both on the energy E_d dissipated by brake disks 5, and on the operating temperature of brake disks 5, i.e. on the way in which energy is dissipated. In other words, the same amount of dissipated energy E_d produces a different

amount of wear on the braking area, depending on whether it is dissipated during extreme (typically on-track) use of vehicle 1, in which brake disks 5 reach high temperatures (of over 400/500°C), or during normal use
5 (typically on public highways). More specifically, the same amount of dissipated energy E_d produces much greater wear of the braking area during extreme, as opposed to normal, use of vehicle 1.

For these reasons, in a preferred embodiment,
10 constant K may assume two different values corresponding respectively to normal and extreme use of vehicle 1. To distinguish between the type of use of vehicle 1, a braking mode assessment is made, and the instantaneous wear contribution u of brake disks 5 during deceleration
15 is determined on the basis of the value E_d of the energy dissipated by brake disks 5 during deceleration, and on the basis of the braking mode assessment, which is obviously directly related to the temperature of brake disks 5 during deceleration.

20 The braking mode assessment is made on the basis of a mean value of kinetic energy differential DE_k within a given time interval, which typically ranges between 0,1 and 5 seconds and may cover a number of successive decelerations brought about by a number of successive
25 operations of brake system 4. If the mean value of kinetic energy differential DE_k exceeds a given threshold, this means vehicle 1 is undergoing a series of sharp, repeated decelerations, i.e. is being used in

extreme conditions, and constant K assumes a higher value. Conversely, if the mean value of kinetic energy differential DEk is below the given threshold, this means vehicle 1 is not undergoing a series of sharp, repeated
5 decelerations, i.e. is being used in normal conditions, and constant K assumes a lower value.

In alternative embodiments, constant K may assume one value, regardless of how vehicle 1 is used, or may assume more than two values as a function of the braking
10 mode assessment, and in particular as a function of the mean value of kinetic energy differential DEk.

Tests confirm the ability of central control unit 8, as described above, to determine the total wear value U of brake disks 5 extremely accurately, thus enabling a
15 prompt, accurate driver warning signal indicating the need to change brake disks 5.